Productive Rural Infrastructure Sector Project

in the Central Highlands of Vietnam

BIOENGINEERING REPORT

November 2012

CONTENTS

I. Executive Summary:

Objective(s): To use bioengineering techniques in rehabilitation and stabilizing road and irrigation schemes and restoring areas of native vegetation damaged as a consequence of project works.
Performance Criteria: Rapid establishment and dense coverage of vegetation to bioengineering and re-instated areas, and minimal erosion of bioengineering and re-instated areas.
Responsibility: The organizational responsibilities for each stage are defined as per management consequences under the PRIDP. The relevant stage associated with each management action is denoted as follows: (D) = Design (T) = Training (C) = Construction (O) = Operation
Management Action(s): Protect finished areas of exposed soil on road embankments and table drains to be achieved by planting with local species (D), (C) and (O). Where appropriate, engage local villages in the establishment, planting and maintenance of bioengineering and re-instated areas (T), (C) and (O). Regular maintenance (e.g. weeding, watering, and erosion control) shall be undertaken in bioengineering and re-instated areas to ensure rapid establishment and dense vegetation coverage is achieved during construction and following post construction period (C) and (O).
Monitoring: Regular inspections of bioengineering and re-instatement works shall be undertaken to ensure compliance with management actions.
Reporting: Any erosion or significant loss of vegetation in bioengineering or re-instatement works shall be reported to the Supervising Consultant.
Corrective Action: Implement appropriate corrective management actions as required to prevent continued erosion and/or replace, and prevent continued loss of, vegetation in bioengineering or re-instated areas.

II. SUMMARY

1.1 The purpose of this report is to identify a way forward for bio-engineering approaches for the Productive Rural Infrastructure Project (PRIP), sustainability and climate resilience for the investment project in general, and the representative subprojects. In particular, the concern is the application of bio-engineering techniques for soil and water stabilization. It is based on the one month Bioengineer input, which is followed by two time intermittent inputs for the fifteen days from August 12-25 and October 29 to November 17, 2012 respectively. The two inputs in the different time periods is intended to produce the following outputs: (a) Prepare a realistic principle approaches and implementation strategy for bioengineering works (b) Site assessments, cost estimates, design and drawing for the three representative sub-projects under the PRIDP. A terms of reference of the Bio-engineer

is provided in the annex of this report.

1.2 There is a significant demand for the adoption of bio-engineering techniques to assist in stabilizing associated erosion problems during the improvement of rural infrastructures under the project. The most important sites for bio-engineering techniques are in slope stabilization and in protecting new cut back, spoil disposal and existing erosion made during access road improvements for the defined sub-projects. Bio-engineering techniques are well suited to these types of situations and it is recommended that techniques including the following are adopted: brush layers, grass planting, shrub and tree planting, seeding and bamboo planting. On longer sections of realignment involving cuttings suitable bio-engineering techniques include the use of grasses planted in diagonal lines, supplemented by bamboo as live spurs to provide protection from physical scours. In more extreme circumstances, bio-engineering techniques can be used in conjunction with engineering measures to stabilize roadside slope. The report has also outlined simple and appropriate straightforward bioengineering techniques in the Central Highland provinces.

1.3 This report also identifies opportunities for increased participation of local communities in the Bioengineering works. It recommends that a program of forestry extension is supported to improve general land management and increase the number of trees in the vicinity of the roads and irrigation infrastructures. Local participation is considered to be necessary in order to address the soil erosion issues at the project sites. The consultant has initiated from site assessments suitable plant species and nurseries, scheduling, preparation of standard design drawing and specification, rates analysis and quantity estimation for roadside bio-engineering works.

1.4 It is recommended that a serious effort be made to successfully implement bio-engineering techniques in the project. To assist in fulfilling this purpose, the project will need to be resourced with adequate technical training in the Bioengineering aspect. The report has also focused on the capacity development of the bioengineering through extension and training program. The project will also require the employment of a qualified supervision consultant staff to achieve high standard bioengineering program during an actual project implementation stage.

1.5 Finally, A sustainability of the infrastructure measures will depend largely, in many cases, on the arrangement made between the local stakeholders and the Project. It is strongly suggested that ethnic minority farmers from the project implementation province be most involved in the Bio-engineering works, providing extension and training programs enabling sustainable livelihood development of pro poor people living in the project vicinity.

iii. ILLUSTRATIONS OF EXISITNG SOIL EROSION ISSUES

1. Gia Lai Province (GL-03), Upgrading completeness of Rural infrastructures, Tan Son Irrigation works in Nghia Hung-Chu Jor Commune, Chu P ah District.

Embankment erosion of Ton Son dams resulting in an enormous amount of surface materials into cannels to down slope. Installation rows of brush layers along the slope would held surface materials on the slope

The same area of Ton Son dams. This photographs shows how the slope has eroded and blocked the irrigation channel across the embankment. This lead to expensive maintenance costs.

Eroding either side of the slope in clay materials discharging debris into carriageway of the channel. Such erosion can be easily prevented by planting grasses and trees/shrubs, along with coordinating local people to assist with plants selection, protection and management.

A

slope failure in the colluvium debris over flow into the gully bed triggering erosion to irrigation infrastructures. A concrete masonry wall at the bottom of the slope and. implementing Bio-engineering measures would be appropriate to stabilise the slope

2. Kon Tum Province (KT-01), Repair and upgrading of Kon Trang Kla and Dak Trit Irrigation system and the rural infrastructure in Dak La area, Dak Ha district.

An upgrading road to Dak Trit Irrigation. Bio-engineering works along with tree plantation would help to stabilise road banks protection as well as reinstate natural vegetation to the proposed rural road area.

A long section of slope shows failure above the road. It is cut into two different slope segments. The slope needs trimming and Bio-engineering measures during upgrading the road section.

An overview of typical problems created by soil erosion and careless spoil disposal in the Dak Trit irrigation reservoir area. The cut slope is unprotected and soils are eroding hence filling to reservoir. The project needs to seriously tackle these problems in conjunction with civil and Bio-engineering measures.

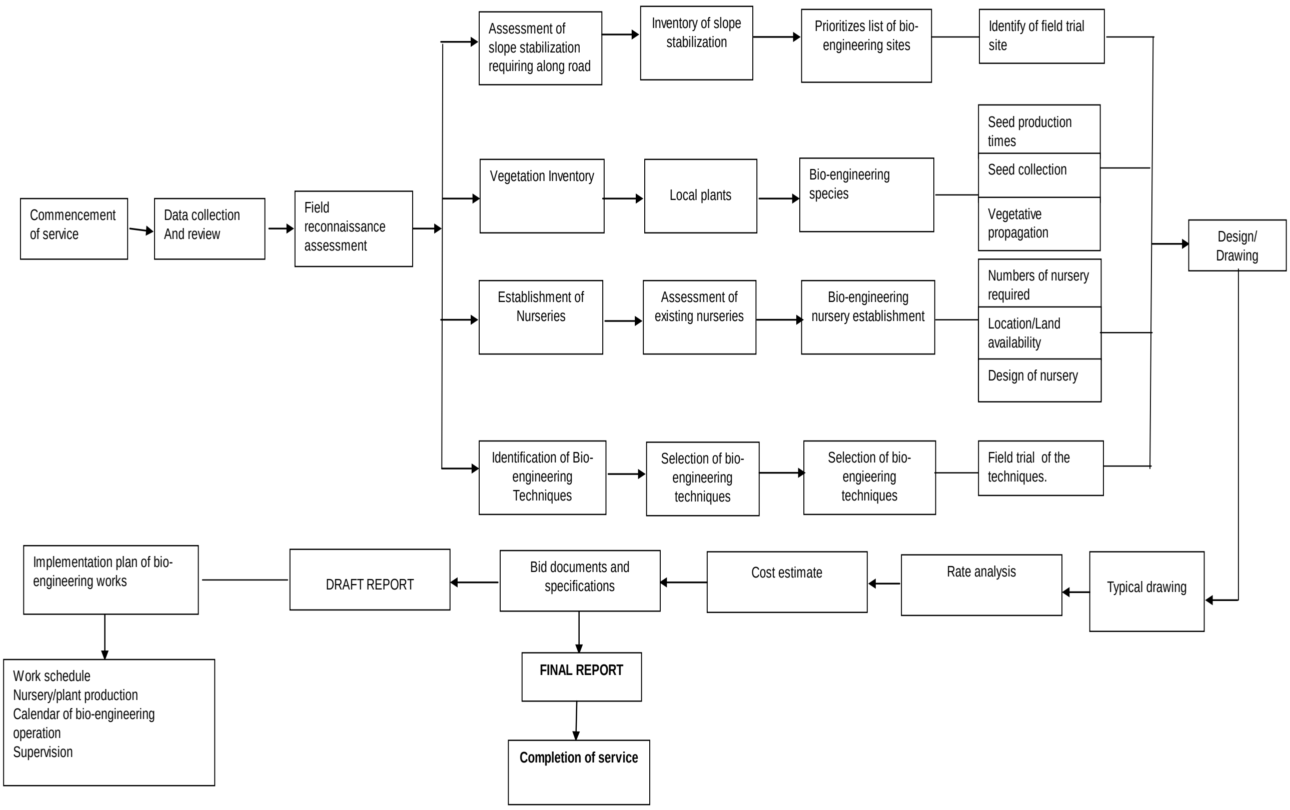
Sedimentation or siltation is one of the severe threats to irrigation dams and reservoirs. The project is required to use best bio-engineering approaches for erosion and runoff control.

1. INTRODUCTION

The Bioengineering program in PRIDP will provide an opportunity for testing appropriate means of bio-engineering implementation and establishment, including the operation of plant nurseries if required to support this program. Potential benefits from implementation of bio-engineering include not only the cost effective protection of roadside slopes and costly engineering infrastructures, but opportunities for the involvement of interested and affected stakeholders, including indigenous pro poor people for the livelihood improvement and sustainable land management in the project vicinity.

Bio-engineering activity flow program has been made to show the methodology and approaches to carry out the Bioengineering program in the Productive Rural Infrastructure Development Project (PRDIP).

Table-1: *Bio-engineering Activity Flow Program.*



In order to document the required bio-engineering measures, this report presents a preliminary assessment of existing erosion problems in the proposed projects in the central highland, assesses the suitable bio-engineering plant species and an inventory of plants, identifies Bioengineering techniques, nursery requirements for the plants to be supplied for the Bioengineering program, and consequences to expedite the bio-engineering program in the selected sub-projects. The report also considers opportunities for local participation in operation and subsequent implementation of a bio-engineering program.

The consultant Bioengineer also had opportunities to meet and discuss soil erosion issues of the general public and with many of the technical staff of both central project management unit (CPMU), and technical staff of PPTA assignment for the PRIDP.

2. USE OF BIO-ENGINEERING

The infrastructures development of any project causes adverse environmental consequences. The only cost effective way to protect slopes against erosion and shallow landslides is through the use of bio-engineering. Bio-engineering is the use of living plants for engineering purposes. Plants are carefully selected for the functions they can serve in protecting slopes. It is usually used in

combination with civil engineering structures to offer more effective solutions because the materials and skills are all locally available.

- Bio-engineering is used to protect slopes against erosion.
- Bio-engineering reduces shallow planar sliding.
- Bio-engineering is also used to improve surface drainage and reduce slumping.

Bio-engineering is the most effective and economic solution to address shallow-seated problems. The use of bio-engineering techniques may cost more in the short term, but over the long term there should be additional benefits from reduced maintenance costs.

The strength of a structure at various stages of its life can be related to its maximum strength. Figure 1 shows how this is different for bio-engineering and civil engineering structures: vegetation takes a few years to reach maximum strength. As the relative strength of civil engineering structures decrease, however, the relative strength of plant structures increases.

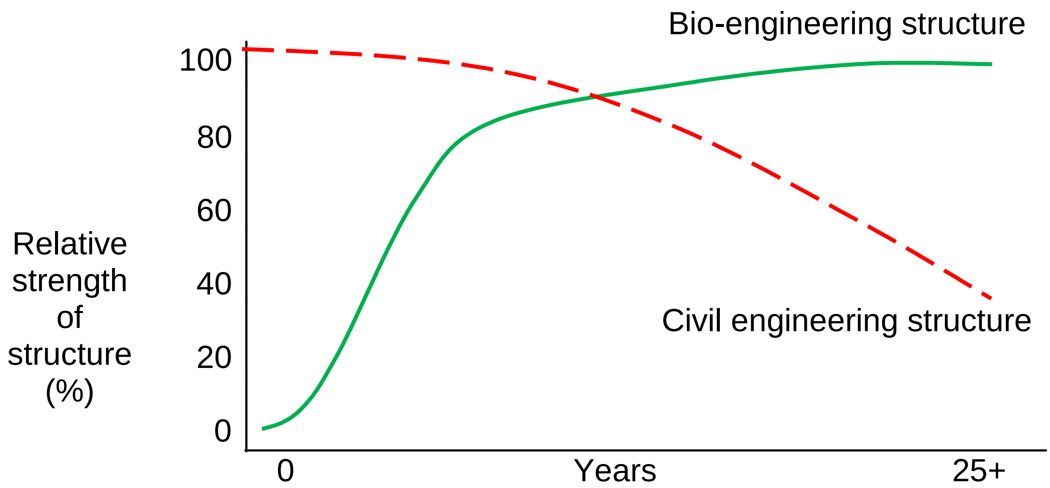


Figure 1 - Life span of small civil engineering and bio-engineering structures

This covers a range of techniques that can be combined with civil engineering structures to enhance drainage and slope stability. In a climate dominated by monsoon rains, the seasons of work implementation cannot be altered. Failure to undertake bio-engineering works at the right time increases the risk of instability and slope failures in the near future.

2.1 SELECTION OF THE BIOENGINEERING TECHNIQUES

Selection of proper bio-engineering measures for slope stabilization is not simple. Most slope erosion and landslides have more than one cause of mechanism failure operating at different points on the slope. Separate parts of a landslide have to be given different treatments, appropriate to the mechanism of failure. There are many factors which need to be considered carefully before any planning for remedial measures are undertaken during the PRIDP implementation. The most important factors are careful site examination and attention to details.

Emphasis should be placed on techniques which improve slope drainage, since the problems of high infiltration and low cohesion are found in the materials. The widespread prevalence of subsistence agriculture means that there is a heavy degree of reliance on all natural resources, and almost all plants provide some benefits to neighboring cultivators. Without surface protection, erosion can be rapid and severe, affecting slopes considerable distances above and below roads.

If the environmental damage repair is taken further, then bio-engineering offers a great deal more than just protection against erosion. The right combinations of plants can help to restore agricultural systems or forests, and thereby mitigate some of the damage caused by the construction or presence of a road. As Howell (1999) showed, bio-engineering sites can be managed
in such a way as to become productive plantations or parts of well managed farm units.

Figure 2 - Local people showing an initiative to protect the terraces bank by planting grasses.

Bio-engineering works by fulfilling the engineering functions required for the protection and stabilisation of slopes. The plants must provide one or more functions of catching debris, armouring the surface, reinforcing the soil, anchoring the surface layer, supporting the slope or draining the material. Plants used in combination provide much greater effect than single plants. If a line of grasses is planted across a slope, together they form a continuous line to catch debris, and provide a line of reinforcement. The contour line of grass will also increase the infiltration capacity of the soil. Drainage function can be achieved using grass lines by angling the lines across the slope. It is important to ensure that the slope is armoured against erosion. Grasses are the best plants to achieve this. But grasses mostly require full sunlight in which to grow; so to sustain a good cover of grasses it is necessary to keep the shrub or tree canopy as thin as possible. Conversely, without the shrubs and trees, the deeper reinforcing and armouring functions required on many sites would not be provided.

Bio-engineering techniques which are suggested in the PRIDP are simple and labour intensive. The skills required are simple, as local already utilise these skills in their agricultural farming. The plants are also easily available in their locality. The local community can manage and maintain the stability of slope by themselves if the project provides enhanced technical and physical support towards the program. Also, this provides valuable jobs to the local people and they can perform income generation activities through the bioengineering process.

The use of indigenous large species planted in different configurations is a simple and yet highly effective means not only of erosion control, but also affecting slope hydrology. The common bioengineering techniques and theirs functions on slope stability suitable in the environment of central highland of Vietnam are summarized in Table-2 below.

Table-2: Common Bio-engineering techniques for the central highland province (CHP)

Technique	Description
Grass planting	Large grass clumps, usually in lines across the slope. Lines are typically horizontal to maximise the protection against erosion; however, on some materials and in certain situations, they are better either diagonal or straight down the slope: these give surface protection while maximising drainage.
Brush layers	Live hardwood cuttings (≈ 20 mm dia., 500 mm length) laid in shallow trenches. These give immediate and increasingly strong protection and reinforcement. As with grass planting, they can also be angled to enhance drainage.
Fascines	Bundles of live hardwood cuttings (≈ 40 mm dia., 1500 mm length) laid in shallow trenches across the slope. These give rapid and increasingly strong protection and reinforcement. As with grass planting, they can also be angled to enhance drainage.
Bamboo planting	Large clumps of bamboos planted at intervals. These are relatively shallow rooting but provide very strong surface protection. They take a few years to establish properly and serve their full function.
Shrub and tree planting	Shrub or tree seedlings planted at intervals. Roots penetrate relatively deeply and provide reinforcement and anchorage. They take a few years to establish properly and serve their full function.
Toe wall with vegetation	A dry stone toe wall is strengthened by planting vegetation in the gaps. This is flexible but provides a strong revetment, without the cost of concrete mortar.
Vegetated stone pitching	Surface protection with stone pitching is strengthened by planting vegetation in the gaps. This is flexible but provides very strong armouring in periodic stream channels, without the cost of concrete mortar.
Site specific	There are numerous options for individual site solutions, depending on specific site requirements. Particular designs are best undertaken in conjunction with geotechnical engineering structures.

2.2 Selection of Bio-engineering Species

The ability of a particular plant to grow in a certain site is determined by the suitability of the species to that site. Plants should become well-established in the season of planting so that they are able to survive the dry months until the next rainy season. Many bio- engineering sites have extremely poor and stony soils, which drain rapidly. The species should be robust enough to fulfill the bio-engineering function. Vegetation growth depends upon the temperature and moisture conditions for which the species is adapted. Species used for bio-engineering have a tolerance for site conditions and grow on almost any site, depending on specific characteristics. Water is the main factor for plant growth in the warmer months. The use of pioneer species for bio-engineering on bare roadside slopes helps to allow a vegetation community to establish through the development of shade and better soil. The factors contributing to the final choice of species are:

- The species that will address the specific problems for bio-engineering techniques.
- Types of appropriate propagation techniques.
- Suitable species for the environmental conditions on site.
- Performance of the required functions on site and also usefulness to local farmers.

- Availability of species at the right place, at the right time, and in the right quantities.

Local species are generally better suited to local conditions than species introduced from another area. This means that the choice should normally be a species found in the area where the bio-engineering is being implemented. Many of the recommended bio-engineering plants are pioneer species, which means that they are naturally adapted to grow and survive on poor sites with extremes of sunlight, heat, drought and low nutrition levels. The main points related to the establishment of stable natural vegetation are:

- Use of fast-growing species for rapid establishment.
- Establishment of a stable, easily maintained plant community.
- Development of a vegetation cover that will reduce erosion.
- Development of a canopy which shades the soil and improves rooting conditions.

Many bio-engineering sites in the sub-projects are in inhabited areas. Local farmers may be able to make use of the plants grown on the sites. Wherever possible, the choice of species should be made with the consideration that products are of potential use to local people.

3. GENERAL ENVIRONMENT AROUND THE PROJECT AREA

The assessment of landforms, terrain, slopes and natural stability suggests that most natural slopes in the central highland Vietnam are inherently stable except under extraordinary rainfall conditions. There is evidence that the steeper mountain slopes have been subject to greater instability in the past (there are signs of ancient landslides and gullies), but under current environmental conditions, natural stability seems to be the norm. However, landslides, debris flows and gully activation may occur occasionally as a result of extreme storm events. It is likely that the stability of many slopes is marginal, and disturbance arising from an extreme rainfall event can push them beyond the threshold of stability. There can be no doubt that these storms occur and give rise to occasional devastating slope damage, but there is inadequate data to understand the situation in detail. The *Vietnam Hydro meteorological Atlas* shows severe flood discharge levels for rivers in certain areas, and these must be generated by high intensities of rainfall. Field observations and common knowledge suggest that major problems of this nature are relatively rare, although they do occur more frequently in the central belt between 15 and 18° north.

The inter annual variations of rainfall are mainly influenced by seasonal winds, monthly rainfall and temperature over the Central Highland of Vietnam. The annual rainfall ranges from 1500 to 2400 mm. Monthly rainfall is concentrated from May to October, accounting for about 80% of the annual rainfall amount. The average monthly rainfall during the rainy season exceeds 200 mm. The peak of rainfall is observed in August and September due to tropical cyclones and typhoons during this period. The air temperature ranges from 20 to 25^0 C. The highest temperatures are observed in April and May, corresponding to rapid warming of the landmass that causes the onset of the SASM, with atmospheric circulation over mid and low latitudes [Yanai et al. 1992].

Combined with generally steep slopes, thin soils and heavy seasonal rains have resulted in landslides and erosion of soil from mountains thus making transportation difficult. Soil erosion and slope failure represents a hazard in the sector that is costly in both financial and environmental terms. The number of shallow slope failures and gully erosion which occur are related to deficiencies in maintenance of drainages and cut slopes. Relatively, deep seated landslides are found on Colluvial soils on many slopes steeper than 40º angles. This appears to be a natural phenomenon that affects roads and other infrastructures to different scales. The fragility of this terrain makes treatment more complex and problematic for engineers who design any permanent structures.

Against this scenario, there is a human side which must also be considered. The project area of the central highland provinces are populated by subsistence farmers who require all of the resources available in order to make a living. The hill section of CHP's have a low rate of productivity, and

rapidly rising environmental degradation throughout the hills is leading to an excessive and unsustainable use of natural resources and destroying of natural forest for agriculture. Although this is perhaps of little direct concern to the project, it becomes important here as such land use activities in the area have an adverse impact on slope stability along the project area. An unmanaged land use practices on hill slope has often contributed to the deforestation of the side and a gradual increase of erosion events on slopes (figure: 3). To rectify this situation it is essential to ensure direct and indirect negative impacts to the roads and the surrounding environment are minimized. Similarly, it is important to minimize further damage by reinstating roadside vegetation as far as possible through cost effective means.

Figure-3: Local indigenous people harvesting food from very drought land in Gia Lai province.

3.1 EXISTING SITUATION

There are numerous small and incipient erosion and instability problems that have affected the existing irrigation and roads side slopes, and they will continue to be affected unless appropriate action is taken. The most common classes of these are as follows. Site assessments photographs of the two sub-projects situated respectively in the Kon Tum and Gia Lai province are shown in the Annex-1of this report.

- In many cases the washing out of slopes triggers the development of classic translational and rotational failures, or some form of erosion gully, on the valley side slope. This may cause a failure of the formation, either immediately or after expansion of the slide over one or two rainy seasons (Figure-4).
- Weak sections of the bare slope fail, blocking and perhaps also damaging or blocking the carriageway of the irrigation.
- Small failures in cut slopes develop into erosion gullies or shallow mass failures. These supply additional debris to the dams and reservoirs to canals, damage the pavement, and generate follow-on down slope problems (Figure-5).
- Shallow failures develop in fill slopes, often as a result of slope surcharging due to the repeated tipping of debris below the retaining structure as shown in Figure-6.
- Slow-moving but creeping slides form in gentle slopes below roads crossing unconsolidated deep, heavy clays.

Figure-4: Uncontrolled water discharge from Irrigation canal created huge gully erosion problem. Sub-Project No-1 upgrading irrigation system in Dak Nong Province.

4. EXECUTION ASPECT OF THE BIO-ENGINEERING WORKS

It is almost certain that effective participation of the local people is required for long term protection of the costly infrastructures, including bio-engineering installations. This has also been demonstrated from the experience of similar types of projects in other developing countries. Therefore, it will be useful for PRIDP to seek and undertake bio-engineering activities by involving active participation of local community from the very beginning of the project. By doing this, it is envisioned that the program will be mutually beneficial both to the project and local community residing along the project corridor

Fig-5: A suitable grass species are available in the project for the Bio-engineering planting in the project area.

Fig-6: A good example of local participants for the protection of side slopes by planting local grass.

The local community will be able to enhance their social and economic welfare by more productive support from the project, while the project will be able to fulfill the objectives of sustainable development in addition to the protection of road and irrigation structures from landslides and other anticipated erosion problems. Over the course of time, genuine and long–lasting cooperation and

participation should be established with the local community and line agencies for sustainable implementation of the bio-engineering program.

It is considered that the local community participation in the bio-engineering program will be more effective and enhanced if the following aspects are taken into consideration during the project implementation under PRIDP:

- Planning and coordination of the program with an experienced supervision team with respect to effective community liaison, house hold survey, practical training, in hand supervision, and various issues merged in operation and implementation of the program through community participation.

- Involvement of interested and affected stakeholders of roadside neighbours in the bio-engineering program and its extension.

- From the very beginning, providing opportunity and means of responsibility sharing to/with the community in protection and aftercare of the bio-engineering sites followed by their participation in implementation of the bio-engineering works. The participation through group organization will be more effective.

- Providing planting materials as per side neighbours preferences and involving them in plantation. Similarly, allowing them to have sustainable use of the trees species and grasses planted on their side of land.

- Mobilization of experienced and efficient bio-engineering staff to work closely with the local people.

- Promotion of useful ideas and practice through training and allocation of tools and materials for site works.

- Coordination and liaison with related government agencies like NGO'S, Forestry and soil conservation etc. for achieving help and support in long term executing of the program.

5. RECOMMENDED PROGRAM FOR BIO-ENGINEERING

The bio-engineering program in the road construction project has generally been found to be more successful if it enlists the cooperation of the local communities within the vicinity of the road project. Therefore, it would be advantageous to involve the local community in the bio-engineering activities, by splitting into two main components in the PRIDP project:

a. Bio-Engineering for roadside slopes, irrigation dams and other infrastructures protection.
b. Extension program for road-based community.

An objective of both components has to be the protection of the roadside slopes; irrigation infrastructure as well as to effectively protect the road corridor against man made destruction and natural erosion. However, the function and working methodology of both components are characteristically different and they are outlined below:

a. Bio-Engineering for roadside slope protection

- In conjunction with engineering techniques, to stabilize all erosive area and cut slopes on both side of the road.
- To minimize surface erosion on all soft materials in cut slopes and batters by means of grass planting where appropriate.

- To prevent riling between the road surface and the side drain on all embankments by means of revegetation with grasses.
- To minimize shedding of small scale debris from rocky cuts, by the direct seeding of shrubs.
- Where appropriate, to reduce infiltration into slope using grasses planted in specific line configuration.

b. Extension program for irrigation based community

- To encourage the local people to keep cultivation back from the edge of all slopes by planting lines of perennial grasses and trees.
- To improve the strength and integrity of agricultural terraces by encouraging people to plant and maintain more trees on their land.
- To improve the quality and management of forest resources close to the road by encouraging management by the local community.

6. FEASIBILITY STUDY FOR IMPLEMETATION OF THE BIO-ENGINEERING WORK

6.1 Site assessment

As already stated, there is a huge demand of the bio-engineering work to improve the infrastructures maintenance regime in Central Highland Province (CHP). The site assessment covering to the FS sub-projects Kon Tum and Gia Lai provinces has been done during the site visits, which is provided in Table-3 in below. However, as there will certainly be many changes occurring over time, the implementation consultant should complete detailed site by site assessments of each of the sub-projects during the project implementation stage. A standard site assessment format for the Bioengineering work has been developed and provided in Annex - 1. Subsequently, a typical bio-engineering designs suitable to mitigate existing erosion problem for the sub-projects has been presented in Annex- 2 .Similarly, a specification guidelines for implementation of the recommended Bio-engineering techniques has been shown in Annex-4 of the report.

Table-3: Site Assessment of Kon Tum and Gia Lai

Description	Bio-Technique	Description	Advantages	Remarks
Kon Tum (KT-01) & Gia Lai (GL-03)				
Irrigation: Dam +spill way /feeder canal	**Channel bank erosion protection measures**			
Debris tipped from cut slopes surcharging the materials to dam caused siltation, surface and rills erosion on embankment sloes of the dam, banks erosion in irrigation canals.	Palisades	Lines of live hardwood cuttings are planted along the edge of the waterway channel.	A low cost method of establishing robust vegetation along a channel bank.	Refer to typical Bio-engineering designs (Annex-1 and specification s Annex-3
	Bamboo planting	Lines of bamboo clumps are established along the edge of the waterway channel.	A low cost method of establishing very robust and productive vegetation along banks.	
	Bio-engineering measures	Various methods of surface protection using grass, tree/shrub and brush layering.		
	Tree planting	Lines of trees are planted along the edge of the waterway channel.	A low cost method of establishing very robust and productive vegetation along banks.	
Upgrading rural roads sector	**Roadside slope stabilization and erosion control**			
Road side slope failure, rills and gully erosion and valley side slopes erosion	Slope trimming and spoil disposal	Slopes are trimmed to a suitable grade according to material characteristics.	Slope stability is maximised and the chance of subsequent damage is	

		Spoil is disposed of safely in approved locations.	minimised.	
	Check dams	Small dams are constructed in gullies to impede the speed of water flow and thereby reduce erosion.	Check dams can be designed according to site conditions.	
	Stone pitching	A slope is armoured against erosion by placing a surface covering of stones.	A low cost, flexible solution for slopes with high rates of surface flow.	
	Bio-engineering techniques	Various methods of surface protection using grass, tree/shrub and brush layering.	The only cost effective way of preventing erosion over large areas of slopes.	

6.2 Identification of Bio-engineering plant species

The ecology of Central Highland Province (CHP) is influenced by its topography, dominated by mountain ecosystems and inland habitat, and a bio-diverse mountain region. Central Highland Province (CHP) has a humid tropical climate and different plant life compared with the north, the south, east, and mountain regions. Regarding the bio-engineering plants, various types of vegetation communities are found when the alignment crosses different altitudes, soils exposition, aspect, and drainage and land use of eastern and western coast in Central Highland Province (CHP).

Of the varieties of vegetation communities, the most interesting from the slope stability viewpoint, are those that colonise disturbed ground. There are a wide variety of grasses that rapidly appear in these sites. Among them the deep rooted spreading species *Thysolaena maxima* and *Pennissetum clandestinum* are most common on fill areas and former cultivated soils. On heavier clays and more compacted surfaces, the deeper-rooting clump grass seems to be very useful. The large bamboos *Dendrocalmus hamiltonii and Bambusa nutans*, is naturalized and capable of colonising all but the driest of slopes. Various tree/shrubs such as species *Schimia wallichii, Alnus nepalensis, Machilus gamblei, Ficus nerifolia, Litsea monopetala,* and *Prunus carasoides* are also common pioneers on bare soils. All of these plants (and many others, including various pioneer shrubs and trees) appear where disturbed land is abandoned. However, their appearance on roadside slopes is mixed, and many of the harder cut slopes are slow to re-vegetate.

An assessment of suitable plant species (tree/shrubs, grasses and bamboos) for the purpose of bio-engineering work has been prepared and given in Table -4 on the following page.

Table-4: Assessment of plant species for the Bio-engineering works

S.N	Local name	Botanical Name	Remark
Trees			
1	Sao đen	Hopea odorata	Local people demand
2	Xoan ta	Melia azedarach	Best use for the bioengineering
3	Bạch đàn	Eucalyptus camaldulensis	Best use for the Bioengineering
4	Lim xanh	Albizia lebbeck	Best use for the Bioengineering
5	Keo tai tượng	Acacia mangium	
6	Thông ba lá	Pinus kesiya	Best use for the Bioengineering and local use
7	Bời lời	Litsea glutinosa	Best use for the Bioengineering and local use
8	Dầu rái	Dipterocarpus alatus	Best use for the Bioengineering and local use
9	Xoan nhừ	Choerospondias axillaris	Best use for the Bioengineering
10	Thông tre lá ngắn	Podocarpus pilgeri	Best use for the Bioengineering and local use
11	Giổi xanh	Michelia mediocris Dandy	Indigenous tree
12	Bời lời đỏ	Litsea glutinosa	Indigenous tree
13	Tre đá	Dendrocalamus hamiltonii	Indigenous tree, best use for the Bioengineering
14	Tre lồ ô	Bambusa balcooa	Indigenous tree, best use for the Bioengineering

S.N	Local name	Botanical Name	Remark
15	Tre vầu	Bambusa nutans	Indigenous tree, best use for the Bioengineering
16	Giang	Ampelocalamus patellaris	Indigenous tree, best use for the Bioengineering
17	Lồ ô	Schizostachyum spl	Indigenous tree
18	Nứa	Schizostachyum sp2	Indigenous tree
19	Thành Ngạnh	Cratoxylon formosum	Indigenous tree
20	Đẻn	Vitex canesxens	Indigenous tree
21	Giáng hương	Pterocarpus macrocarpinus	Indigenous tree

Shrubs			
1	Keo dậu	Leucaena leucocephala	Good for bioengineering
2	Ngũ sắc	Lantana camara	Indigenous tree, best use for the Bioengineering
3	Cây Xuân Tiết, Cang mai	Adhatoda vasica	Indigenous tree, best use for the Bioengineering
4	Cây liễu bốn hạt	Salix tetrasperma	Indigenous tree, best use for the Bioengineering
5	Dứa sợi Mỹ	Agave americana	Indigenous tree, best use for the Bioengineering
6	Ngũ chảo	Vitex negundo	Indigenous tree, best use for the Bioengineering
7	Thẩu tấu lông hoe	Aporosa filicifolia	Indigenous trees
8	Thẩu tấu răng	Aporosa serrata	Indigenous trees
9	Lá nến	Macaranga denticulata	Indigenous trees
10	Bùm bụp nâu	Mallotus paniculatus	Indigenous trees
11	Thành ngạnh	Cratoxylon formosum	Indigenous trees
12	Sổ trứng	Dillenia ovata	Indigenous trees
13	Chà hiêu nhẵn	Wendlandia glabrata	Indigenous trees
14	Cò ke lá lõm	Grewia tomentosa	Indigenous trees
15	Bứa nhỏ	Garcinia sp.	Indigenous trees
16	Tuế lá xẻ	Cycas micholitzii	Indigenous trees
Grasses			
1	Vetiver	vetiveria lawsoni	Best use for the Bioengineering
2	Ghine grass	Panicum maximum	Best use for the Bioengineering
3	Cỏ lá tre	Acroceras munroanum	Best use for the Bioengineering
4	Cỏ gà	Cynodon dactylon	Best use for the Bioengineering
5	Cỏ tranh	Imperata cylindrica	
6	Cỏ voi	Panicum sarmentosum	
7	Cỏ đót	Thysanolaena maxima	Best use for the Bioengineering
8	Sậy khô	Neyraudia reynaudiana	Best use for the Bioengineering
9	Cỏ bông lau	saccharum spontaneum	Best use for the Bioengineering
10	Trúc thảo Nepal	Arundinella nepalensis	Best use for the Bioengineering

6.3 Bio-engineering Plant Nursery Sites

Large quantities of planting materials are required for the bio-engineering sites in the sub-projects under PRIDP. Fortunately, there is an existing nursery operating under the private owner around the project vicinity. This nursery could be a good source if sufficient coordination is established from the beginning to the supply of plants required in bio-engineering sites on respective sub-projects. For this purpose, the nurseries were thoroughly visited and also were involved with assessing the area to fulfill the requirements of the bio-engineering nursery. Details of existing plant nurseries are provided in preceding page in this report. It is suggested that the nursery should be able to supply the plants raised in poly pots having following characteristics:

- ✓ A bright, healthy colour;
- ✓ No visible signs of wilting;
- ✓ Growing fast, with long new shoots;
- ✓ Keep with root pruned;
- ✓ Kept moist throughout the soil cylinder;
- ✓ Well weeded;
- ✓ Without sign of discoloration on the leaves;
- ✓ Without sign of insect attack on the leaves;
- ✓ Without any obvious signs of disease;
- ✓ Undamaged

Existing Plants Nursery in Kon Tum and Gia Lai Provinces

I: Kon Tum province:
1. Chu lai nursery:

Address: Thanh Trung village, Vinh Quang commune, Kon Tum city.
Nursery areas is 2 ha, this nursery is management by private sector in Chu Lai. The nursery provides forest seedling and urban trees.

The list of tree which provided by nursery Chu Lai:

NO.	Trees	Latin name	Cost (VND)	Remark
1	Keo	Acacia mangium	700	
2	Xoan	Melia azedarach	700	
3	Bời Lời	Litsea glutinosa	700	
4	Cà Phê	Coffea	1.500	
5	Cao Su	Hevea brasiliensis	20.000	
6	Cari	Trigonella foenum-graecum	3.000	
7	Sao đen	Hopea odorata	3.000	
8	Sưa	Dalbergia tonkinensis	10.000	
9	Bạch đàn	Eucalyptus Camaldulensis	7.000	

10	Thông	Pinus kesiya	7.000	

2. Dak Ha extension station nursery:

Address: 5 village, Ha Mong commune, Dac Ha district, Kon Tum province.
Nursery areas are 2 ha which management by extension station and usually provide seedling for many project in the districts.

No.	Trees	Latin name	Cost (VND)	Remark
1	Keo	Acacia mangium	700	
2	Xoan	Melia azedarach	700	
3	Bời Lời	Litsea glutinosa	700	
4	Cà Phê	Coffea	22.000	
5	Cao Su	Hevea brasiliensis	18.000	
6	Sao đen	Hopea odorata	3.000	
7	Sưa	Dalbergia tonkinensis	10.000	

II: Gia Lai province:

1. Private nursery:

Address: Road National 14, yen the district, Pleyku city, Gia Lai province.

The list of tress which are provided by this nursery:

No.	Trees	Latin name	Cost (VND)	Remark
1	Trắc	Dalbergia cochinchinensis	10.000	
2	Sưa	Dalbergia tonkinensis	10.000	
3	Sao đen	Hopea odorata	10.000	
4	Xà cừ	Khaya senegalensis	10.000	
5	Bằng Lăng	Lagerstroemia speciosa	5.000	
6	Bời Lời	Litsea glutinosa	3.000	
7	Hồng lộc	Syzygium campanulatum	5.000	
8	Dầu rái	Dipterocarpus alatus	1.000	
9	Thông 3 lá	Pinus kesiya	700	
10	Keo	Acacia mangium	700	

6.4 Rate Analysis for Bio-engineering Works

The rate analysis including plants from nursery supply for the bio-engineering program for the Sub-projects has been undertaken during the report preparation. A detailed illustration of rate analysis of each item for the bioengineering is shown in Annex-3, whereas an item wise summary of the rates are as shown in Table-5.

6.5 Section wise bio-engineering quantities requirements

A summary of approximate Bioengineering quantities and costs for three sub-projects is provided in table 6. The quantity stipulated may vary during the final surveyed design of each site as it covers more than the straightforward planting of trees and grasses. Nevertheless, the cost of bio-engineering is very minimal with respect to the long term protection to the side environment and erosion.

6.6 Work Program

An annual work program for the bio-engineering work applicable to overall PRIDP project sectors has been prepared and is shown in Table-7. It is based on local environment and rainfalls in Central Highland Province (CHP) and encompasses all necessary activities from Nursery development, training, plantation management, work supervision and until plantation is completed over a one year period.

Table-5: Unit Rates for Bio-engineering Work

S.no	Item	Unit	Rate (VND)	Remarks
1	Slope trimming including all operations.	m^2	4,895	
2	Final slope preparation including all operation.	m^2	50,000	
3	Removal of debris and loose surplus materials from slope and tipping to approved location within 1km	m^3	78,842	
4	Planting rooted grass slips on slopes 45-60º including preparation of slips on site.	m^2	69,685	
5	Grass seeding and mulching including placing of wide square jute nets on slopes to 45-60º.	m^2	176,128	
6	Planting containerized tree seedlings, including pitting, transplanting, composting and placing tree guards.	nos	147,576	
7	Shrub seeding on rocky patches of slope including all preparation.	m^2	176,128	
8	Planting bamboo stumps, including pitting, transplanting, composting and placing tree guards.	nos	329,758	
9	Construction of Brush layers including all preparation.	m	126,315	
10	Construction of fascines and live palisades including all preparation.	m	275,672	
11	Construction of dry stone check dams including supply of boulders and all preparation,	m^3	499,028	
12	Construction of stone rip-rap of 300mm thick and including all preparation.	m^2	158,070	
13	Maintenance and aftercare	LS		

Table-6: A summary of Bioengineering Works for three sub-projects.

S.No	Description of Work	Unit	Rate (VND)	PRIDP Sub-Projects						
				DAK LAk		KON TUM		GIA LAI		Total
				Qty	Costs	Qty	Costs	Qty	Costs	Amount
1	Slope trimming including all operations.	m^2	4,895	500	2,447,280	3,000	14,683,680	2,348	11,492,427	28,623,387
2	Final slope preparation including all operations.	m^2	50,000	350	17,500,000	2,375	118,750,000	1,890	94,500,000	230,750,000
3	Removal of debris and loose surplus materials from slope and tipping to approved location within 1km of the road.	m^3	78,842	200	15,768,302	500	39,420,755	600	47,304,906	102,493,963
4	Planting rooted grass slips on slopes 45-60º including preparation of slips on site.	m^2	69,685	200	13,937,000	2,500	174,212,500	2,519	175,536,515	363,686,015
5	Grass seeding and mulching including placing including wide square jute nets on slopes to 45-60º.	m^2	176,128	100	17,612,760	1,709	301,002,068	15,721	2,768,902,000	3,087,516,828
6	Planting containerized tree seedlings, including pitting, transplanting, composting and placing tree guards.	nos	147,576	2,000	295,152,000	4,000	590,304,000	3,689	544,407,864	1,429,863,864
7	Shrub seeding on rocky patches of slope including all preparation.	m^2	176,128	350	61,644,660	700	123,289,320	578	101,801,753	286,735,733
8	Planting bamboo stumps, including pitting, transplanting, composting and placing tree guards.	nos	329,758	231	76,174,098	1,000	329,758,000	879	289,857,282	695,789,380
9	Construction of Brush layers including all preparation.	m	126,315	432	54,568,166	525	66,315,480	467	58,989,198	179,872,845
10	Construction of fascines and live palisades including all preparation.	m	275,672	324	89,317,728	500	137,836,000	500	137,836,000	364,989,728
11	Construction of dry stone check dams including supply of boulders and all preparation,	m^3	499,028	466	232,547,141	400	199,611,280	400	199,611,280	631,769,701
12	Construction of stone rip-rap of 300mm thick and including all preparation.	m^2	158,070	325	51,372,750	400	63,228,000	400	63,228,000	177,828,750
13	Maintenance and aftercare	Lums um	100,000,000		100,000,000		100,000,000		100,000,000	300,000,000
TOTAL AMOUNT VND for three sub-projects					**1,028,041,886**		**2,258,411,083**		**4,593,467,225**	**7,879,920,194**
GRAND TOTAL AMOUNT										

Table-7: Bio-engineering Annual Works Program

Productive Rural Infrastrucutres Development Project (PRIDP)

Table 7 Annual Works Programme for Bio-engineering

S. No	Activity / Project Month	PRIDP Jan	Feb	Mar	Apr	May	jun	Jul	Aug	sep	Oct	Nov	Dec
A	**Preparatory work for plants production**												
1	Determine an approved exisitying and new nurseries location												
3	Calculate the plants and species to be produced and arrangements for production.												
B.	**Training on Nursery management and Bio-engineering works**												
1	Participants and location arrangements for the training .												
2	Conduct nursery management and operation training												
3	Conduct bio-engineering application techniques training on site works												
B.	**Nursery establishment and operation.**												
1	Calculate the size and fix area for nursery.												
2	Construction of physical infrastrucutures (i.e fencing, nursery beds, roofing, and water supply.)												
3	Supply of tools required in nursery.												
4	Supply of top soil , compost and sand for polybags filling.												
5	Filling polybags of												
6	Seedscollection and preparation of all plants.												
7	Seed sowing of tree/shrubs.												
8	Routine activities (Watering, caring to plants, seedling transplanting, weeding, root purning etc)												
9	Complete plant production.												
10	Extraction of plants from nursery to site for planting.												
B.	**Site planting, management and supervision**												
1	Mobilization of supervision staff and manpower.												
2	Planting tools arrangement for plantation.												
3	Transport and supply tree/shrubs from nursery to site.												
4	Collection, and preparation of local available planting materials (grass slips, live cuttings and bmboos) and supply to planting site.												
5	Carry out plantation work												
6	Complete all plantation work.												
D.	**Maintenance, Aftercare and protection.**												

HOTTEST AND DRIEST TIME OF YEAR

RAINING TIME OF YEAR

6.7 Financial implication

It will certainly be necessary for the PRIDP to make adequate funds available if any worthwhile work is to be carried out and offer positive impact on the bio-engineering program. The consequences of not carrying out this program will be greatly added additional costs to maintain the infrastructures. Also, the project goal for the local capacity building will not be met, as well as the enhanced protection of the natural environment.

7. ACTION PLAN

This section provides a suggested strategy for a realistic way forward for the implementation of bio-engineering works under the PRIDP. This strategy is based on findings of the site assessments described previously. The success of bio-engineering implementation will largely depend on effective action plan for the program. Therefore, it is suggested that the project action plan is integrated with the annual work program outlined in Table-8. If it is not followed successfully, then the quality of the bio-engineering outcomes will be poor, and the benefits may be limited.

***Table 8**: Action Plan for the Bio-Engineering operation*

Activity	Action	Action completed by
Strategy		
Approval of suggested timing	Central Project management Unit (CPMU)discuss and approve	To be decided as per project implementation period
Estimated cost consequences	CPMU discuss and approve	
Selection Bio-Engineering supervision Consultant		
Selection of supervision consultant	CPMU	
Approval of consultant	“	
Consultant start work	“	
Management contractors specialist selected	“	
Contractors specialist approved	“	
Management contractors start works	“	
Bio-Engineering Training		
Select the participants	Supervision consultant	
Training course arranged for the Local community and contractor staff	“	
Training sequences repeated as per roads section	“	
Identify local community participation and deliver training	“	
Nursery establishment and operation	Management Contractors	
Determine nursery sites and construction of nursery	Management Contractors	
Start nursery operation, compost production, seed collection, sowing, pots filling, transplanting	“	
Complete plant production	“	
Scheduling of works		
Reschedule Bio-engineering sites as per original site inventory	Supervision Consultant	
Preparation Bioengineering package	“	

for section		
Bio-engineering site works		
Site preparation works	Management Contractors	
Start physical structures works on slopes	"	
Implementation of the Bio-engineering works	"	
Extraction of plants from nursery	"	
Complete Bio-engineering work	"	
Works maintained	"	
Evaluation of Bio-engineering work	"	
Arrangement of Bio-engineering sequences repeated every year as per project period	"	→

8. Recommendation

The bio-engineering is an essential part of the slope stabilization throughout productive rural infrastructure development project (PRIDP) in the central highland. The use of vegetation is an appropriate part of this and represents an ideal form of development in design of the road sector improvement project. The bio-engineering is in initial stages of its implications in the Vietnamese environment and the construction approaches require a relatively high level of expertise of this field. The skills required are significantly different from those used in engineering, forestry and agriculture. Because the techniques involved are relatively new, this means that quality assurance is essential in order to ensure that the desired effect is achieved. If the expected result is to be attained there must be the following adequate provisions suggested below:

- It is recommended that an expatriate should be recruited to work full time as Bio-engineering specialist during the supervision period. He/She would be responsible for planning, designing and training and supervision of the work and implementing its execution via contractor's or relative agencies.
- There should be a large requirement of construction training to enhance qualitative progress on construction activities around in country. Therefore, a Bio-engineering specialist would also work on preparation of training methodology, hand-out and other materials to conduct training among the road engineer's, inspectors, supervisors and contractors.
- Practical Bio-engineering training must be provided in the contractors and community level, and the training would also incorporate construction of structures like gabion walls, slope drainages and other structures. The two weeks of training would be suitable for this and it will have to be repeated as per the construction progress.
- The bio-engineering nursery should be established and operated under the community responsibility. Arrangement should be made to run such nursery by local community participation. The supervision consultant should assist more on logistics and technical matters. During the course of time, options should be explored to enable operation of the bio-engineering nursery for the road maintenance purpose.
- All the slope must be finished to an even, straight profile of the specific steepness for the successfully implementation of the bio-engineering works. It is essential that the contractor finishes the slope works well in time, before the rains start and bio-engineering works need to be implemented.

Annex- Terms of reference for the International Bio-engineer

TA 9743 VIE - PPTA
Productive Rural Infrastructure Development Project in the Central Highlands
Project Preparatory Technical Assistance (PPTA)

Bio-Engineer (International) (1.267 PM)
Terms of Reference for Contract Variation

Original TOR for the Bio-Engineer (1 PM – 30 days)

1. Provide guidance to the national bio-engineer to assist in carrying out the following tasks;
2. Coordinate with the other engineers and the environment/climate change specialist in the application of bio-engineering techniques for soil and water stabilization;
3. Prepare a matrix of approaches and associated species to protect the PRI against soil erosion, shallow planar sliding on sloping terrain, improve surface drainage and reduce slumping;
4. Prepare guidelines for bio-engineering systems for protecting PRI for;
    a. Catching moving eroding materials
    b. Armouring slopes against surface erosion from both runoff and rain splash
    c. Reinforcing the soil through root networks to resist shear forces
    d. Anchoring the surface materials through root systems to firmer strata below
    e. Support the soil mass by buttressing and arching using a range of selected vegetation
    f. Drain excess water from slopes while avoiding soil saturation by appropriate configuration of selected of vegetation
5. Prepare guidelines for restoring or constructing stable slopes geometry for PRI
6. Apply the above (1 – 4) in conjunction with the irrigation and civil engineering work for the three representative subprojects
7. Provide a framework for the identification and implementation of bio-engineering measures on subprojects to be taken up under the overall project

Additional Activities (Additional 0.267 PM – 8 days)
It was clear from the field visits there was very little understanding of the potential for bio-engineering in addressing CCR. In addition, the high proportion of road works within the subproject mix renders greater opportunities for bio-engineering interventions. Consequently, the following additional activities are proposed in the course of conducting the feasibility studies on the three representative subprojects:

1. Site assessments and inventory preparation specific to the subprojects;
2. Identification of actual plant species for the projects sites;
3. Overview of plants nursery establishment proposals;
4. Raising awareness in provincial departments concerned and with local consultants.

Annex- Terms of reference for the national Bio-engineer

TA 9743 VIE - PPTA

Productive Rural Infrastructure Development Project in the Central Highlands
Project Preparatory Technical Assistance (PPTA)

Bio-Engineer (National) (1.53 PM)
Terms of Reference

Original TOR for the National Bio-Engineer (1.0 PM – 30 days):

1. Support the duties of the International Bio-Engineer; and
2. Carry out survey, design and cost estimation work on the representative subprojects independently in the absence of the International Bio-Engineer.

Additional Activities (Additional 0.533 PM – 16 days)

Support the international Bio-Engineer in the following additional activities proposed in the course of conducting the feasibility studies on the three representative subprojects:

5. Site assessments and inventory preparation specific to the subprojects;
6. Identification of actual plant species for the projects sites;
7. Overview of plants nursery establishment proposals;
8. Raising awareness in provincial departments concerned and with local consultants